# FACTORS AFFECTING THE pH OF HOME-CANNED PEPPERS

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## ABSTRACT

The influence of recipe and raw material on the pH of home-canned peppers was investigated. Acidification levels specified in typical recipes were compared with those found in similar commercial products having acceptable pH values. Green and red peppers representing 12 varieties were analyzed for pH, acidity, and response to acidulation in the raw state and after canning with and without added vinegar. Hungarian Wax and Sweet Cherry peppers were more highly buffered than the other cultivars analyzed, requiring the addition of 1 tbsp vinegar (5% acidity) per pint jar of canned product to reduce the pH to or below 4.6. No less than that quantity of vinegar should be added.


## INTRODUCTION

HOME-CANNED PEPPER products have been implicated in at least 18 outbreaks of botulism (101 cases) in the United States since 1950 (Center for Disease Control 1974, 1976; Gunn and Hatheway, 1977; Snyder and Hatheway, 1978). Growth and toxin production by *Clostridium botulinum* were observed in inoculated green chili peppers and pimientos at pH values above 4.9 but not at pH 4.7 (Townsend et al., 1954). Sane et al. (1950) reported the pH range of raw pimiento peppers to be 5.1–6.3 for mature green pods and 4.7–5.5 for red pods. Because of the potential risk of botulism with this low acid product, Culpepper et al. (1948) recommended that sweet peppers be thermally processed under steam pressure to accomplish the destruction of *C. botulinum* spores. Alternatively, pepper products such as pimientos can be acidified to a pH of 4.6 or lower and then given a less severe thermal process at 100°C. The technology for acidifying pimientos is well established (Powers et al., 1950; Supran et al., 1966; Flora et al., 1978).

Recently published home-canning procedures for peppers and pimientos call for processing in a pressure canner, and in some cases, for the addition of vinegar or lemon juice to make the product more acid (Anon, 1974a; York and De Jong, 1978). Botulism statistics for home-canned peppers suggest, however, that this information is not being properly utilized by home canners. This may be due in part to the continued use of outdated home-canning procedures which call for processing unacidified peppers in a boiling water bath (Anon, 1942; Culpepper et al., 1948). Unsatisfactory canning methods, i.e., the use of a 20 min boiling water bath process or salicylic acid in hot oil to preserve canned peppers, have appeared in a more current publication (Gewanter and Parker, 1975). A recent survey by Kaitz and Davis (1976) has indicated that a substantial proportion of home canners are still using boiling water bath or open kettle canning methods for low-acid vegetables in spite of the well-known danger of botulism inherent with such methods.

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In the present study, we investigated the adequacy of published acidification procedures for home-canned peppers, comparing prescribed acidity levels to those found in similar commercial products and evaluating the influence of pepper variety and ripeness on the effectiveness of acidification.

## MATERIALS & METHODS

### Commercial products

Samples of canned acidified and pickled pepper products were purchased in local food stores. The drained weight of each product and volume of the drained brine were determined by use of a #8 standard sieve and a 2 min draining time (32.002, AOAC, 1970). The drained solids were blended for 2 min at high speed with a Waring Blendor. The pH of the blended solids portion of each product was determined with an expanded scale pH meter. Titratable acidity, calculated as milliequivalents acid per 100g sample, was determined by titrating a 10g sample of blended solids, diluted with 40 ml distilled $H_2O$, with 0.1N NaOH to a pH 8.1 endpoint. Chloride, calculated as sodium chloride, was determined in the drained liquid by $AgNO_3$ titration with a chromate indicator (2.109, AOAC, 1970).

### Recipes for home-canned peppers

Recipes for home-canned unacidified, acidified, and pickled peppers were obtained from cookbooks and home-canning guides. The added acidity and salt content of pepper products made according to these recipes were estimated from the specified ingredient proportions and preparation steps. In order to perform these calculations, we made the following assumptions: (1) The pepper-to-brine ration (weight/volume) for home-canned pickled peppers would be the same as the mean value of the drained weight/brine volume ratio, determined experimentally in our laboratory for similar commercial products, i.e., 1.16 for chili peppers and 1.24 for other pickled whole peppers. (2) The moisture contents of raw and cooked peppers are 93.4 and 94.7%, respectively (Adams, 1975). (3) The bulk density of raw whole peppers is 0.3g/cc (Wright, 1956; Ryall and Lipton, 1972). (4) Peppers soaked in NaCl brine would equilibrate within the specified brining time of the recipe (12–18 hr). (5) Pint jars would be filled to a total volume of 450 ml. (6) Vinegar and lemon juice used to acidify peppers would contain 5% acetic acid and 5% citric acid, respectively.

### Analysis of raw peppers

Samples of raw pepper fruits representing 12 cultivars were harvested at Fordhook Farms, the W. Atlee Burpee Co. experiment station located in Doylestown, Pa., in August and September, 1978. The peppers were picked when mature green or yellow and later when they had ripened to a red coloration. Anaheim, Cayenne, Sweet Banana, Sweet Cherry, and Hungarian Yellow Wax peppers were analyzed whole since they would most likely be canned in this form. Stems and seeds were removed from all other cultivars prior to analysis. Since a minimum sample weight of approximately 100g was required for analysis, the number of individual peppers which were pooled to make up a replicate varied from cultivar to cultivar, depending on fruit size and trimming losses. Fifteen replicates were analyzed for each cultivar and stage of ripeness. Sweet Cherry and Hungarian Wax peppers were blended for 1 min at low speed in a 1,000-ml Waring Blendor jar and then transferred to a semi-micro stainless steel blending container for an additional 2 min blending at high speed. Other pepper samples were blended for 2 min at high speed in the larger blender jar. The pH and titratable acidity of raw pepper homogenates were determined as described previously for processed peppers. In addition, the response of peppers to acidification was determined by diluting 50g aliquots of pepper homogenate with 50 ml $H_2O$ and titrating with vinegar (containing 5% acetic

*Table 1—Acidity, salt content, and drained weight of thermally processed, acidified commercial pepper products*

| Product category | No. products sampled | Pooled subcategories | Acidulant | pH | Titratable acidity[b] | Salt (%) | Ratio of drained wt (kg) to brine vol (L) |
|---|---|---|---|---|---|---|---|
| Cherry peppers, sweet | 2 | — | vinegar | 3.6 | 27.3–29.0 | 2.6– 3.7 | 0.9– 1.4 |
| Cherry peppers, hot | 6 | oil-packed (1) | vinegar | 3.3–3.7 | 26.9–44.2 | 2.7– 5.4 | 0.9– 3.4 |
| Chilies, green | 3 | — | citric acid | 4.0–4.3 | 3.7– 6.4 | 0.8– 1.8 | 2.6–13.1 |
| Chilies, jalapenos | 2 | oil-packed | vinegar | 3.0–3.8 | 16.8–41.6 | 2.8–12.5 | 1.3– 3.3 |
| Chilies, misc. | 2 | red, jalapenos | citric acid | 4.0–4.4 | 6.3– 6.6 | 1.2– 1.9 | 6.0– 6.2 |
| Chilies, misc. | 2 | yellow, cortidos | vinegar | 2.8–3.1 | 29.8–41.4 | 4.1– 6.2 | 1.0– 1.3 |
| Hot peppers, misc. | 4 | rings (2) | vinegar | 3.1–3.5 | 26.9–35.8 | 2.7–11.8 | 0.7– 2.8 |
| Pepperoncini | 4 | citric acid added (2) | vinegar | 3.2–3.4 | 20.5–34.2 | 2.0– 3.0 | 0.8– 1.1 |
| Pepper salad[a] | 2 | pepper piccalilli | vinegar | 3.6–3.7 | 20.8–31.9 | — | 4.2– 9.7 |
| Pimientos | 9 | fire-roasted (2), no acidulant listed (4) | citric acid | 4.0–4.4 | 3.3– 5.1 | 0.0– 0.5 | 1.6– 6.8 |
| Red and yellow peppers | 1 | — | vinegar | 3.5 | 28.2 | 2.0 | 1.9 |
| Salonika peppers | 1 | — | vinegar | 3.2 | 25.3 | 6.6 | 1.5 |
| Sofrito[a] | 1 | — | vinegar | 4.0 | 25.6 | — | — |
| Sweet peppers, red | 2 | — | vinegar | 3.1–3.8 | 15.1–38.6 | 1.6– 2.0 | 0.6– 1.5 |
| Sweet peppers, roasted | 4 | — | citric acid | 3.7–4.2 | 3.5– 6.6 | 0.5– 1.5 | 1.5–51.2 |
| Sweet peppers, misc. | 10 | cheese (1), memento (1), rings (2), wax (1) | vinegar | 3.2–3.6 | 18.6–44.4 | 1.2– 5.2 | 0.6– 1.6 |
| Tabasco peppers | 2 | red, green | vinegar | 2.9 | 69.7–72.6 | 9.6–12.6 | 1.3– 1.5 |
| Taco sauce[a] | 1 | — | none listed | 4.2 | 7.6 | 1.3 | 1.5 |
| Tuscan peppers | 1 | — | vinegar | 3.0 | 25.6 | 4.0 | 1.8 |
| Tomatoes and peppers[a] | 2 | — | none listed | 4.1–4.2 | 6.3 | 1.2– 1.4 | 0.8– 1.1 |

[a] Contains peppers in combination with other vegetables
[b] Milliequivalents acid/100g product

acid) to a pH 4.6 endpoint. Additional pH values were recorded during the titration so that a titration curve could be plotted. The quantity of vinegar required to lower the pH of 100g peppers was calculated from these data.

**Canning of acidified and pickled peppers**

Green and red pepper fruits of six varieties were canned according to the procedure of Thurber and Mead (1976), modified as described below, so that the effectiveness of different levels of acidification could be evaluated. The peppers were washed, trimmed to remove stems and blemishes, and either subdivided into strips with seed removal (Canape Hybrid, Cubanelle), subdivided into cross-cuts without seed removal (Anaheim M and Hungarian Yellow Wax), or left intact (Sweet Cherry). The peppers were then blanched in boiling water for 3 min and packed into eight 1-pt jars to a net weight of 350g (300g for Sweet Cherry). Three grams NaCl (equivalent to ½ tsp) were added to each jar. Two jars served as unacidified controls. Duplicate jars of peppers were acidified with 7.5, 15, or 22.5 ml (corresponding to ½, 1, or 1½ tbsp, respectively) of distilled white vinegar containing 5% acetic acid. Boiling water was added to each jar to give a net weight of approximately 445g (425g for Sweet Cherry). Jars were sealed and processed for 35 min at 10 lb pressure. A composite sample of raw peppers, taken from the same lot of peppers used for canning, and weighing approximately 120–150g, was homogenized and analyzed for pH, titratable acidity, and response to acidification, as described previously.

Canned products were equilibrated at room temperature for one month. The peppers were then blended for 30 sec at high speed in a Waring Blendor and analyzed for pH and titratable acidity, as described previously.

## RESULTS & DISCUSSION

**Commercial pepper products**

Data on the composition of a number of categories of pepper products are presented in Table 1. None of these products had pH values exceeding 4.6, the proposed upper limit for such foods. We have classified the samples into two groups on the basis of their acidity: the pickled products that have a pH of 4 or lower and contain more than 15 meq acid/100g, added as vinegar; and the acidified products that are above pH 4 and contain less than 10 meq acid/100g, usually added as citric acid.

Within each product category, the titratable acidity, salt content, and drained weight-brine volume ratio varied by as much as two- to fourfold, presumably because of differences in product recipes and ingredients. The diversity of commercial pepper products with respect to types and differences in composition is probably a good indication of variation to be found in home-canned peppers, prepared according to traditional or published recipes.

*—Continued on next page*

*Table 2—Comparison of recipes for home-canned pepper products*

| Product | Thermal process | Acidulant | Added acid | | Added NaCl (%)[a] | Reference |
|---|---|---|---|---|---|---|
| | | | tbsp/pint | Meq/100g product[a] | | |
| Canned peppers | 35 min at 10 psi | none | — | — | 0.67 | Anon (1974b) |
| | 35 min at 10 psi | vinegar | 1 | 2.8 | 0.67 | Thurber and Mead (1976) |
| | 50 min at 5 psi | vinegar | ½ | 1.4 | 0.67 | York and De Jong (1978) |
| | 50 min at 5 psi | vinegar | 1 | 2.8 | 0.67 | Nichols (1973) |
| | 50 min at 5 psi | lemon juice | ½ | 1.3 | 0.67 | Nichols (1973) |
| Canned pimientos | 15 min at 10 psi | none | — | — | — | Anon (1974a) |
| | 20 min at 10 psi | vinegar | 1 | 2.8 | 0.67 | Thurber and Mead (1976) |
| Pickled peppers | 15 min at 77–88° | vinegar | — | 18.6 | 0.67 | York and De Jong (1978) |
| Pickled jalapeno peppers | 10 min at 100° | vinegar | — | 28.9 | 0.88 | Anon (1974b) |
| Pickled peppers | 10 min at 100° | vinegar | — | 30.2 | 8.44 | McNair (1975) |

[a] Calculated assuming pepper/brine = 1.24

### Adequacy of recipes for home-canned peppers

Ten published recipes for home-canned bell peppers, pimientos, and pickled peppers are summarized in Table 2. Values of added acid and salt were estimated from information contained in the recipes and assumptions described previously.

Recipes for home-canned bell peppers and pimientos call for pressure canning with (Thurber and Mead, 1976) or without (Anon, 1974a) prior acidification. Levels of acidification prescribed by these recipes fall within the range of titratable acidity values (corrected for endogenous acid; see Table 3) found in comparable commercial products which had pH values below 4.6. Likewise, recipes for pickled peppers specify levels of vinegar addition equivalent to titratable acidity values found in commercial pickled pepper products having pH values between 3 and 4. Acidulation with ½ tbsp lemon juice or vinegar per pint jar of product (1.3–1.4 meq/100g), as specified by several recipes for canned peppers, may be marginally effective with pepper varieties containing less endogenous acid. Powers et al. (1950) concluded that 1.9–3.2 meq citric acid per 100g (150–250 mg per 4 oz can) were required to lower the pH of canned pimientos to 4.5.

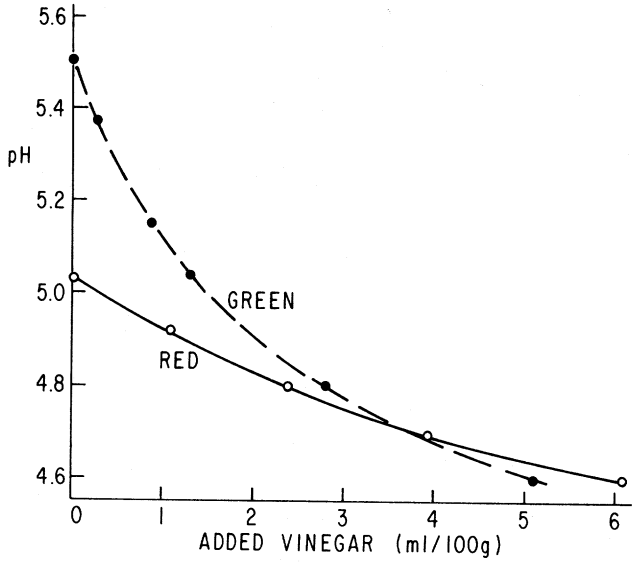


*Fig. 1—pH of acidified raw Sweet Cherry peppers.*

Inconsistencies between acidification levels and thermal processing conditions called for by these recipes are noteworthy. Acidification is intended to lower thermal processing requirements so that product texture and flavor will not be damaged (Nichols, 1973). Yet the thermal process specified by the Kerr Canning Book (Anon, 1974b) for unacidified bell peppers is similar to that specified by Thurber and Mead (1976) for acidified peppers. Similarly, thermal processes specified in pimiento recipes are inconsistent, the most severe process being used for the acidified product.

### Varietal differences in pepper acidity

The acidity of a home-canned pepper product depends on the acidity and buffering properties of the raw material as well as on the recipe. The 12 pepper varieties that were analyzed varied in pH from 5.4–6.0 in the green stage and from 4.8–5.3 in the red stage of ripeness (Table 3). The decrease in pH of 0.4–1.0 unit, which occurred during ripening, was accompanied by large increases in titratable acidity with all varieties. Similar results were obtained by Sane et al. (1950) with pimientos.

The pH of pepper fruits acidified with vinegar was nonlinearly related to the quantity of added acid (Fig. 1). Sapers et al. (1977, 1978b) previously reported a linear relationship between the pH of tomatoes and added acid. The response of peppers to acidification varied both with variety and stage of ripeness. With some varieties such as Canape Hybrid and Cubanelle, red peppers required less vinegar for pH reduction than did green peppers. Other varieties such as Hungarian Wax and Sweet Cherry showed the opposite behavior, more vinegar being required with red peppers. Flora et al. (1978) reported that the quantity of citric acid required to lower the pH of pimientos to a given value was greater in ripe pimientos in spite of their lower initial pH.

A pH value of 4.6 may be considered an appropriate target for the acidification of canned peppers since this pH should prevent the outgrowth of *C. botulinum* spores if the product were to be given an inadequate thermal process. The quantity of vinegar required to lower the pH of raw pepper samples to 4.6 (Table 3) varied from a low value of 2.7 ml per 100g for red Goldsmith's Early Prolific and red Cubanelle to as much as 6.6 ml per 100g for red Sweet Cherry. These acidification requirements correspond to a

*Table 3—Acidity of green and red pepper fruits*

| Variety | Fruits/replicate[a] | pH | | Titratable acidity[b] | | Vinegar addition to pH 4.6[c] | |
|---|---|---|---|---|---|---|---|
| | | Green | Red | Green | Red | Green | Red |
| Anaheim M | 3 | 5.5 | 4.9 | 1.4 | 4.7 | 3.2 | 3.1 |
| Bell Boy Hybrid | 1 | 5.5 | – | 1.3 | – | 3.1 | – |
| Burpee Tasty Hybrid | 2 | 5.6 | 4.9 | 1.0 | 4.3 | 3.0 | 3.0 |
| Canape Hybrid | 2 | 5.6 | 4.9 | 1.6 | 4.3 | 3.6 | 3.0 |
| Cayenne, Long Slim[d] | 5-8 | 5.6 | 5.0 | 1.8 | 5.0 | 4.4 | 4.4 |
| Cubanelle | 2-3 | 5.8 | 4.8 | 1.3 | 4.8 | 4.3 | 2.7 |
| Goldsmith's Early Prolific | 2 | 5.4 | 4.8 | 1.4 | 4.3 | 3.3 | 2.7 |
| Hungarian Yellow wax | 2 | 5.7 | 5.3 | 2.0 | 3.5 | 4.2 | 5.3 |
| New Ace Hybrid | 1 | 5.5 | 4.9 | 1.2 | 4.0 | 3.5 | 3.0 |
| Pimiento | 3 | 6.0 | – | 1.0 | – | 3.6 | – |
| Sweet Banana | 2 | 5.5 | 5.0 | 1.8 | 4.3 | 4.0 | 4.0 |
| Sweet Cherry | 7-8 | 5.6 | 5.2 | 2.9 | 5.3 | 5.7 | 6.6 |

[a] Fifteen replicates per sample
[b] Milliequivalents acid per 100g peppers
[c] ml vinegar (5% acetic acid) per 100g peppers
[d] Eight replicates only for red Cayenne

*Table 4–pH of canned acidified peppers*

| Variety | Fruit color | Predicted acid requirement[a] | pH | | | | | Titratable acidity[b] | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Added vinegar (ml/jar) | | | | | | |
| | | | Raw | 0 | 7.5 | 15.0 | 22.5 | Raw | Canned, unacidified |
| Anaheim M | green | 16.9 | 5.5 | 4.8 | 4.5 | 4.4 | 4.2 | 1.3 | 1.8 |
| | red | 7.7 | 4.8 | 4.7 | 4.5 | 4.3 | 4.3 | 3.9 | 3.7 |
| Canape Hybrid | green | 10.3 | 5.2 | 4.9 | 4.5 | 4.3 | 4.2 | 1.4 | 1.5 |
| | red | 8.4 | 4.8 | 4.7 | 4.5 | 4.3 | 4.2 | 3.3 | 3.1 |
| Cubanelle | green | 11.3 | 5.5 | 4.8 | 4.5 | 4.3 | 4.2 | 0.9 | 1.6 |
| | red | 5.5 | 4.8 | 4.6 | 4.4 | 4.3 | 4.2 | 3.2 | 3.1 |
| Hungarian Wax | yellow | 12.7 | 5.7 | 4.9 | 4.6 | 4.4 | 4.2 | 1.0 | 1.7 |
| | red | 14.6 | 5.1 | 4.8 | 4.6 | 4.4 | 4.4 | 3.4 | 3.0 |
| New Ace Hybrid | green | 10.8 | 5.2 | 4.8 | 4.5 | 4.3 | – | 2.3 | 1.8 |
| | red | 7.4 | 4.9 | 4.7 | 4.5 | 4.3 | 4.2 | 2.9 | 2.6 |
| Sweet Cherry | green | 15.3 | 5.5 | 5.0 | 4.7 | 4.5 | 4.4 | 1.6 | 2.8 |
| | red | 18.2 | 5.0 | 4.9 | 4.7 | 4.6 | 4.5 | 3.6 | 4.1 |

[a] ml vinegar per jar to lower pH to 4.6, based on raw composite
[b] Mew acid/100g peppers

level of addition in canned peppers of between ½ and 1½ tbsp (7.5–22.5 ml) of vinegar (5% acidity) per pint jar of product.

**pH of canned acidified peppers**

To obtain a better estimate of the acidification requirement for canned peppers, we measured pH changes in thermally processed samples containing added vinegar. Data were obtained from six pepper varieties at green (or yellow) and red stages of ripeness (Table 4). Unacidified canned peppers were consistently lower in pH than were composite samples of the raw material used for canning. This difference was greater with green peppers than with red peppers. For some varieties, the pH change in green peppers which resulted from canning was accompanied by a small increase in titratable acidity. Sane et al. (1950) also observed a decrease in pepper pH during processing. In contrast to results obtained previously with canned tomatoes (Sapers et al., 1978a), the pH decrease in unacidified canned peppers could not be attributed to added NaCl; samples prepared with and without salt were similar in pH. The pH change may be due to the formation of acidic breakdown products by pectic enzymes before such enzymes are inactivated during blanching. Stadtman et al. (1977) attributed acidity differences between "cold-break" and "hot-break" tomato juice samples to the action of pectinesterase.

The pH of canned acidified peppers in this study was reduced to 4.6 or below by the addition of 1 tbsp (15 ml) of vinegar (5% acidity) per pint jar of product. The pH of canned Sweet Cherry peppers, a highly buffered variety was unacceptably high (4.7), and the pH of Hungarian Wax peppers was marginal (4.6) when ½ tbsp (7.5 ml) of vinegar was added. The addition of more than 1 tbsp of vinegar per pint, i.e., 1½ tbsp (22.5 ml), does not appear to be necessary. Green (or yellow) and red peppers were generally similar in their response to acidification. Acidification requirements predicted from raw pepper titration curves were greater than the amounts of acid actually required for pH reduction to or below 4.6 in canned peppers, perhaps because of the pH-lowering effect of thermal processing. Flora et al. (1978) found that more acid was required to lower the pH of processed pimientos than would be expected from data obtained with peeled and blanched but unprocessed pimientos. They attributed this difference to the neutralization of added acid during processing. Our data do not support this observation; in fact, the titratable acidity of canned acidified peppers in our study was essentially equal to the sum of endogenous acid and added acid.

## CONCLUSIONS

RECIPES for home-canned peppers are inconsistent with regard to thermal processing conditions and the need for acidification. The addition of 1 tbsp of vinegar (5% acidity) per pint jar of canned peppers will effectively lower the product pH to or below 4.6, even with highly buffered pepper varieties. We suggest that this level of acidification be used in conjunction with a thermal process designed for the unacidified low-acid product. Although one cannot anticipate all possible mistakes that home canners might make, the combination of two treatments, each of which precludes outgrowth by *C. botulinum* spores, should greatly reduce the risk of botulism from improperly canned peppers.

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